A new indirect approach to the type-2 fuzzy systems modeling and design

M.H. Fazel Zarandi a,b,⇑, A. Doostparast Torshizi a, I.B. Turksen b,c, B. Rezaee a

a Department of Industrial Engineering, Amirkabir University of Technology (Tehran Polytechnic), Tehran, Iran
b Knowledge Intelligent Systems Laboratory, University of Toronto, Toronto, Canada
c Department of Industrial Engineering, TOBB University of Economics and Technology, Sogutozu, Ankara, Turkey

A B S T R A C T

This paper proposes a new method for designing Interval Type-2 Fuzzy Logic Systems (IT2 FLSs) considering two issues: first, quality of clustering the output space and secondly, approximating the output of the IT2 FLS based on a new output processing method. Based on these two issues, we present a new cluster validity index capable of being used for type-1 Fuzzy C-Means (FCMs), Interval Type-2 FCM (IT2 FCM), and Possibilistic C-Means (PCMs) clustering algorithms. This validity index is highly efficient in determining clusters with the least similarity between them and the highest similarity between data vectors in each cluster. Then, a new definition for uncertainty bounds is presented in order to eliminate the type-reduction process in IT2 FLSs and to increase accuracy of the existing uncertainty bounds in the literature. Finally, effectiveness of the proposed approaches compared to several well-known existing methods has been investigated. Computational results have verified accuracy and effectiveness of the proposed method.

1. Introduction

Fuzzy sets and systems are very useful tools in dealing with uncertain and ill-defined environment parameters where traditional mathematics is not able to give reasonable results. On the other hand, many researches such as [39,40,43] emphasize on limitations of type-1 Fuzzy Sets (FSs) in handling uncertainties since their membership values are crisp rather than fuzzy. T2 FSs were introduced by Zadeh [58] as an extension of type-1 FSs. Type-2 FSs are characterized with type-2 membership functions which are fuzzy themselves. According to [11,21,43], implementation of IT2 fuzzy systems can dramatically improve the performance of the predicted model compared to type-1 fuzzy systems, e.g., [17,19].

In many real-world problems involving pattern recognition, system identification and modeling, forecasting time series, and decision making available data is quite often of uncertain nature [1]. According to [33], such uncertainties may arise from different sources including: (1) the words that are used in antecedents and consequents of rules can mean different things to different people, (2) consequents obtained by polling a group of experts will not necessarily be in agreement; and (3) noisy training data. Antecedent or consequent uncertainties translate into uncertain antecedent or consequent membership functions. Type-1 FLSs, whose membership functions are type-1 FSs are unable to handle the uncertainties directly.

According to [51], the most appropriate situations for applying IT2 FLSs are as follows: